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February 26, 1975

H-3-13

MEMO TO: J. R. Harbison
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Chairman, Research Committee

SUBJECT: Research Report No. 420, "Engineering Data System for Bedrock Occurrences and Properties;" KYP-64-13; HPR-PL-1(10), Part III.

A data bank of statewide soil properties was accumulated from pavement studies in 1947 and 1948 (Reports 37 and 41). In 1955, we began to associate these and other data with pedological classifications and agricultural soils maps. Since 1958, we have cooperated reciprocally with the Soil Conservation Service in this way. From July 1963 to June 1966, this work was financed in part with HPR funds (KYHPR-64-13, "Engineering Properties of Soils"); the work has continued under Study No. KYP-64-13. In 1968, the study was expanded to include bedrock data; and the title was changed to "Engineering Geognosy" [cf. HPR-1(5), Part III]. Most of the soil and rock data come from subsurface explorations done in connection with highway location, bridge-site borings, and landslide investigations. In 1970, special borings were made in connection with a feasibility study for a proposed tunnel (US 119) through Pine Mountain; forty-seven rock quality data sets were generated and referenced. In 1973, soils data were recovered from the Department's plans and construction records. Soil and rock data are being merged with geologic quadrangle maps in a series of engineering geognosy reports; a pending report will cover the Mississippian Plateau. The following reports have been issued:

14. *Proposed Working Plan for a Survey and Pedological Classification of Kentucky Soils in Accordance with Highway Engineering Usage,* March 1946.
73. *Geological Considerations in Relation to a Materials Survey,* Young, J. L., Jr. and Gregg, L. E., 1951; also **Bulletin 62**, Highway Research Board, 1952.
91. *Applications of Geology to Highway Engineering in Kentucky,* Gregg, L. E. and Havens, J. H.; February 1953.
115. *Kentucky Soils: Their Origin, Distribution and Engineering Properties,* Deen, R. C.; March 1956; also **Bulletin No. 40,** Engineering Experiment Station, University of Kentucky, June.
122. *A Method of Developing Engineering Soil Maps for Kentucky, A Pilot Survey of Fayette County,* Deen, R. C.; August 1957; also *An Engineering Soil Survey of Fayette County, Kentucky,* **Bulletin 213**, Highway Research Board, 1959; also thesis, MSCE, University of Kentucky, 1957.
131. *An Engineering Soil Survey of Mercer County, Kentucky,* Deen, R. C.; July 1958.
229. *A General Survey of Highway Construction Materials, Jefferson County (A Pilot Study),* Havens, J. H. and Deen, R. C.; December 1965.
232. *A General Survey of Highway Construction Materials, Jackson Purchase Region,* Deen, R. C. and Havens, J. H.; March 1966.
238. *Engineering Properties of Kentucky Soils,* Deen, R. C.; August 1966.
245. *Highway Construction in Windblown Silts of Western Kentucky,* Deen, R. C.; January 1967.

279. *Engineering Geognosy of Boyd County,* Hopkins, T. C. and Pigman, J. G.; August 1969.
281. *Engineering Geognosy of Warren County,* Pigman, J. G. and Hopkins, T. C.; October 1969.
283. *Selected Features of Kentucky Geology from Lexington to Pineville,* Southgate, H. F.; Hopkins, T. C.; and Scott, G. D.; October 1969.
367. *Engineering Geognosy of the Western Coal Field.* McCann, W.; Hopkins, T. C.; and Deen, R. C.; May 1973.
390. *A Rock Evaluation Schema for Transportation Planning in Kentucky,* Tockstein, C. D. and Palmer, M. W.; May 1974.
407. *Rock Evaluation for Engineered Facilities,* Hagerty, D. J.; Deen, R. C.; Palmer, M. W.; and Tockstein, C. D.; November (prepared for publication by the Transportation Research Board), 1974.

Heretofore, rock qualities were known mostly in terms of aggregate quality tests and building stone test requirements; the in situ qualities of bedrock from the standpoint of foundations and tunneling have been defined more or less on an ad hoc basis. A new discipline, termed Rock Mechanics, has evolved. Nevertheless, descriptions and tests have not yet been standardized fully. Reports 390 and 407 address the problem of selecting and standardizing the most meaningful tests and data to enter into the data bank and the management of the information file from the standpoint of updating and retrieval. Report No. 416 ("Data Acquisition and Management for Rock Evaluation," February 1975) is more in the nature of a large, implementation package; and its distribution will be limited mostly to users. Report No. 407 is a condensation of No. 416 and was prepared for the Transportation Research Board meeting in January 1975 and was not distributed within the Department. After reconsidering the volume of Report 416, we elected to make a distribution of the condensed report -- which is now submitted as No. 420 and retitled as shown at the beginning.

Respectfully submitted,

Jas. H. Havens

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Director of Research

JHH/sh
Enclosure

cc's: Research Committee

Research Report
420

ENGINEERING DATA SYSTEM FOR BEDROCK OCCURRENCES AND PROPERTIES

by

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INTRODUCTION

The need for comprehensive information on the characteristics and behavior of earth materials has been recognized for many years, perhaps for as long as significant construction has taken place in and on the surface of the earth. In recent years, however, the magnitude and complexity of engineered construction has greatly increased, resulting in a corresponding increase in the need for information on the engineering properties of soil and rock materials. Direct testing of soil and rock can be utilized to furnish necessary information. However, both field and laboratory testing can be extremely expensive, particularly where testing must include applications of stress to large masses of earth material. For this reason, significant technical and economic advantages can be realized through the development of indirect or "short-cut" methods for obtaining indications of the properties and characteristics of geologic materials.

Some years ago the value of topographic maps, aerial photographs, pedologic descriptions, and geological surveys in characterizing soil materials was realized. To make this information useful for engineering studies, a serious effort was initiated to obtain data on the engineering properties of various soil groups and associations established on the basis of geological and pedological surveys. The correlation of performance data with information on areal distribution and location furnished by geologic and pedologic works has proven extremely valuable in the planning and construction of facilities in and on soil.

In recent years, the size and importance of structures and facilities designed by engineers and architects has greatly increased. This has produced an increased interest in the rock materials underlying surficial soil layers. A clear need has arisen for a program to provide an engineering evaluation of rock materials for the purposes of location, design, construction, and maintenance of engineered facilities. However, a serious gap exists in the association of engineering characteristics with rock units identified on the basis of geological classifications. Therefore, there is a need for the development of a comprehensive evaluation program which permits utilization of existing data and which aids in the procurement of necessary information on engineering characteristics of rock.

SCOPE OF STUDY

The initial work plan included the development of a classification system based on index tests. An investigation of previous works in classification of rock on the basis of index tests showed that a variety of classification systems utilizing many different index tests had been developed. However, this survey showed that no generally applicable system had been developed and that little communication had been established between field investigators, facility designers, and those in charge of construction and maintenance of facilities. Therefore, the initial plan for work was modified to include the development of a comprehensive methodology for evaluation of rock. The development of such an evaluation schema was to include the establishment of an information bank to provide access to collected data by any interested individual. The first step in the development of this rock evaluation program was a survey of the categories of information that have been collected concerning geologic materials, particularly rock strata. On the basis of this investigation of existing data, a method was devised to collect, categorize, and present more extensive data on rock materials. The general schema for the evaluation program was then developed. At the present time, a research effort is continuing to test and verify the validity of the evaluation program which has been developed. A final step in this effort will be a full implementation of the rock evaluation program for project planning in Kentucky.

GEOLOGIC INFORMATION

Any study of rock materials must rely at least in part on a background of geological information. For several hundred years, geologists have investigated rocks of the earth surface, attempting to organize and codify rock units so that the origin, genesis, and transformation of these units can be properly understood. This work is of tremendous significance for engineering studies of rock materials. Earth materials of concern to the engineer exist in a geological environment. These materials possess physical characteristics which are a function of their mode of origin and subsequent geologic processes that have acted upon them. These events in geologic history lead to a particular lithology, to a particular set of geological structures, and to a particular in-situ state of stress. In the planning, design, construction, and maintenance of engineered facilities, geological structures, distribution of rock types, and variations in existing states of stress in rock materials have significant influence. Additionally, a familiarity with local geologic conditions and information is valuable in that results of past studies and investigations can be incorporated into an information system. This local geologic information can be used to insure that tests selected for classification purposes are compatible with the rocks encountered in a study area. Geologic structures and gelogical materials which have exhibited unfavorable characteristics or which are judged to be potential sources of trouble can be quickly located. Moreover, a knowledge of in-situ stresses can be extremely useful in design. Finally, a knowledge of existing geology in an area under study can provide assistance in the planning and conduct of a testing program for a particular project at a particular site.

In the development of the rock evaluation program for the state of Kentucky, in particular, the geology of the state was reviewed and existing geological information was organized and codified to provide easy access for engineers and technicians not well versed in the topic. The authors recommend that such an organization of geological information be carried out as a primary step in the development of any rock evaluation program in other areas.

ROCK CLASSIFICATION

The organization of geologic information as described in the preceding paragraphs illustrates the basic purpose of any rock classification system: the transfer of information on rock properties from laboratory or field investigators to design engineers and contractors. The optimum means for such transfer of information would be the conduct of tests on rock in its native environment to simulate any proposed construction activity. Behavior of the rock under simulated construction conditions could be monitored and predictions concerning behavior during construction and subsequent operation of the prototype facility could be made. However, the expense of large-scale testing of in-situ rock is such that this approach is not economically feasible. For this reason, inexpensive indirect tests are desirable. If such tests can be developed and used to indicate indirectly the behavior of rock materials under actual construction and operating conditions, great economies can be realized not only in exploration and testing but also in design and construction. Considerable success has been attained in the investigation of soil materials, and to a lesser extent in studies of rock materials, using index testing of samples of material taken from a particular site and predicting performance on the basis of test results and a knowledge of differences between the laboratory test conditions and actual field conditions associated with the proposed facility.

The primary difficulty in the use of index tests for rock characterization lies in the fact that very large samples would be required to test a representative mass of material. Discontinuities located at significant spacings and changes in characteristics of material over long distances would require testing of very large specimens. This cannot be done economically. Therefore, evaluation of rock properties on the basis of index tests must always be considered as a superficial investigation limited on the basis of physical and mathematical continuity considerations. Large-scale rock discontinuities and structural features cannot be preserved in laboratory specimens. These discontinuities and inhomogeneities greatly affect rock deformation and failure in the field. A significant degree of uncertainty will always exist in any prediction of field behavior on the basis of index test results. Nevertheless, index tests can serve as useful indicators of rock behavior, especially in the location and preliminary planning stages. For this reason, the authors have given considerable attention to selecting index properties and using such properties in the classification of rock materials. Index tests must be characterized by simplicity, economy, and ease of performance. Additionally, index test results must be reproducible, within reasonable limits, by various practitioners in various locations using standardized equipment and procedures. Most importantly, the test property must be an index of a material or mechanical property which the design engineer can use effectively.

Many geological classification systems for rock have been proposed. In general, these systems emphasize properties and characteristics of intact material and neglect discontinuities and possible sources of weakness in rock masses which are of critical importance in engineering activities. The most widespread geologic classification of rock has been made on the basis of genesis, and rock materials have been divided into igneous, sedimentary, and metamorphic categories. Within these categories, various subclasses have been developed on the basis of petrographic studies which include characterization of the texture and mineralogy of the rock. In addition to genetic and petrographic classifications, geologists have developed chemical classification systems for rock material which are of limited applicability in engineering studies. Basic genetic classifications have been found to be useful when they can be correlated with the engineering properties of the rock materials. However, in general, genetic classifications are not sufficiently specific and quantitative for use in engineering applications.

Physiographers and geomorphologists have developed systems for classifications of landforms which have proven to be useful as indicators of properties and structures in underlying bedrock. Physiographic classification systems of surficial terrain have proven useful in the location, planning, design, and construction of transportation facilities. The general qualitative character of most geological classification systems has been modified to yield a quantitative methodology of terrain description in the Pattern-Unit-Component-Evaluation (PUCE) system developed in Australia. This quantitative terrain evaluation system appears to be a useful transitional step between purely qualitative geologic classifications and quantitative engineering classification systems for rock.

A number of engineering classification systems have been developed for rock materials. Table 1 summarizes attributes used in classification systems for use with intact rock samples. Some of these systems are based upon inherent rock characteristics while others are based upon a particular purpose or use to which the rock is to be put. Some systems are based upon a combination of inherent characteristics and intended uses. A review of existing classification systems indicated that four basic measures -- strength, lithology, anisotropy, and durability -- can be used to characterize the properties of an intact sample. These characteristics are shown in the form of a classification system in Figure 1.

A variety of tests have been proposed as indicators of rock strength. Uniaxial compressive tests have been used in rock classification systems by a number of individuals. Additionally, hardness tests and various penetration tests have been utilized as indicators of rock strength. Compressive strength tests require machined specimens and thus are somewhat costly in terms of sample preparation. Hardness tests appear to be subject to variations in testing techniques. The point-load strength index has been selected herein as a measure of tensile strength; empirical results show excellent correlation between this index and the unconfined compresssion strength of rock materials.

The lithology of rock materials does not have a direct bearing on mechanical properties, but traditional geologic rock names based on the nature of the texture, mineral content, structure, particle size, and cementing matrix yield significant information on the relation between an intact sample and the rock mass from which the sample was taken. A knowledge of rock lithology can provide an intuitive feeling for the character of the rock mass and can suggest mass effects which may be common to certain groups of rocks.

Almost all rock materials show directional differences in their responses to applied stresses and environmental conditions. For this reason, anisotropy of an intact specimen is of significant interest. The authors have selected point-load test results to define the strength anisotropy index as the ratio between maximum and minimum strength values. In general, this ratio is established by performing the point-load test on specimens oriented so that the load first is applied parallel to the planes of weakness in the specimen and then is applied perpendicularly to those planes.

Behavior of rock materials under long-term changes in environmental conditions can be of significant importance to engineering projects. Durability tests have been used to characterize earth materials as soil or rock and to indicate susceptibility of rock material to alteration in a weathering environment. A large number of durability tests have been suggested by other investigators; swell tests and slake-durability tests have been commonly used. The most successful classification scheme for transitional materials with characteristics intermediate between those of true soils and true rock appears to be that developed by Gamble. The authors have modified this work to yield the system shown in Figure 2. This classification system utilizes values of plasticity index and two-cycle slaking durability. All samples with low plasticity index and durability values greater than 95 percent can be considered rock materials.

Intact sample testing and classification may be sufficient for purposes of preliminary planning and location studies, but the design of facilities will require more comprehensive and direct testing of rock materials and will necessitate examination of in-situ conditions. To satisfy this need, some sort of in-situ classification system is required. Many classification systems involving attributes summarized in Table 2 have been developed by previous investigators. There are relatively few generally applicable in-situ classification systems, which, for the most part, have been evaluation schemes used at particular sites for specific purposes (e.g., for tunneling or blasting requirements).

It appears that the greatest success has been attained by combining tests on intact samples with an analysis of field conditions which tend to govern the behavior of rock materials. Upper limits for strength and deformation resistance may be established on the basis of laboratory tests on intact samples, and these values may be reduced (adjusted) on the basis of field tests which show the influence of discontinuities, weathered zones, etc. Rock models have been prepared to allow an assessment of rock behavior under conditions associated with construction and operation of a proposed facility. The basis of these modeling studies has been, in most cases, a comprehensive survey of discontinuities present at the proposed site of a facility. Since joints are the most widespread discontinuities in rock, in-situ classification systems often include a comprehensive joint survey program. On the basis of a review of existing in-situ classification systems, the authors have developed a classification system as shown in Figure 3. This system is designed to incorporate the effects of discontinuities and mass anisotropy on the characteristics and behavior of the rock. The presence of faults and shear zones has been taken into account by considering these discontinuities in the same way as joints.

PROPOSED ROCK EVALUATION SYSTEM

After the development of the classification systems for intact samples and for in-situ conditions, the next step in the development of an evaluation system was the creation of a method for exchange of information. Results of classification programs would be essentially useless if there were no means to make such information readily available in understandable form to engineers and other investigators involved in design and construction activities. Therefore, a system has been developed to provide engineers with a means to obtain information for site selection, facility design, and construction and maintenance planning. The proposed system consists of two phases: an acquisition segment for the collection and collation of data and an application segment wherein collected data can be used in classification programs and can be analyzed with regard to the use of rock materials in various circumstances. A schematic diagram of the proposed rock evaluation program is shown in Figure 4.

The first segment of the program consists of data acquisition. The central feature of this segment is the data bank wherein information from field and laboratory testing as well as from case histories will be stored. The attributes of the data bank are shown in Figure 5. Information storage is to be accomplished under three categories. Category 1 contains information pertient to the location, identification, and natural environment from which the data (sample or case history information) originated. Category 2 is provided for storage of results of visual observations, index tests, and detailed tests of rock mechanical properties. Category 3 is for the storage of information from case histories and performance reports from contemporary construction and also from completed facilities.

Procurement of data for insertion under Categories 1 and 2 of the data bank will involve both laboratory and field testing techniques. The sample identification sheet shown in Figure 6 shows some of the information required. Samples should be selected on the basis of geological considerations and current availability. Samples should be tested at the site immediately after removal from a core barrel or similar device if at all possible. Since this is not practical in all situations, samples can be returned at their natural moisture content and in a undisturbed condition to a laboratory for further testing. The testing sequence in the laboratory should begin with a swell test and a slake-durability test to provide immediate differentiation between soil and rock materials. The remainder of the information for storage in Category 2 of the data bank can be obtained through index testing and refined laboratory or large scale in-situ tests.

Case history information for inclusion in the data storage system generally cannot be easily quantified. However, a concise version of empirical information can be placed in a coded reference file. The code and identification of site or formation investigated can be entered in the data bank so that when a search is made, the existence of this information will be made known to the investigator. That individual can then conduct further searches for the detailed information on previous experience at a given site or in a particular formation.

The data bank will consist of a system of computer files arranged according to the above-mentioned three categories. Computer programming will be used to facilitate storage, retrieval, and use of acquired information. A sample showing the methodology for storage and retrieval of Category 1 information is shown in Figure 7. The same methodology has been followed for Category 2 and Category 3 data. Figures 8, 9, 10, and 11 illustrate the transfer of information to positions on a computer data card.

Use of the information stored in the data bank can be accomplished through the development of specific classification and application programs. However, a generalized classification can be obtained using the systems shown in Figures 1 and 3. For specific purposes such as the analysis of rock formations for suitability in tunneling operations, a more detailed classification system could be developed. In addition to the use of acquired information in the classification of rock materials, a further use of this information can be achieved through the development of a series of use tables. Such a table is shown in Figure 12. In this sample table, a number of uses (aggregate, rock fill, etc.) for rock materials are shown. The four indices utilized for classification of rock materials can be quantified in terms of acceptable values for the rock material for use in any one of the given ways shown in the table. If a rock is to be used as aggregate in a highway construction project, acceptable values of the point-load index, lithology, strength anisotropy index, and slake-durability index can be developed. Then, any rock available for use in a particular project as aggregate can be tested, and the test values obtained for that rock can be compared with the ranges of acceptable values shown in the table. In this way, the acceptability of various rock units for use in different ways can be quantitatively evaluated. Use tables can be developed for particular applications. For example, Franklin developed a diagram showing "ease of excavation" of rock by blasting, ripping, and digging which was essentially a use table. The diagram was based on ranges of point-load index and fracture frequency. Use tables represent quantitative criteria developed from behavioral models of rock masses.

Use tables and the classification system can be combined in the application segment of the rock evaluation program as shown in Figure 4. This figure represents the combination of the acquisition segment and the application segment into a total rock evaluation schema. A user can request information from the data bank through a selected classification system and use table. The information retrieved from the data bank can be processed in the classification system and a particular site or a particular rock unit can be evaluated for specific uses. The user must then evaluate the data obtained from the data bank. In general, the user must decide whether or not sufficient data has been obtained for the evaluation of a particular site as the location of a proposed facility. If sufficient data has been obtained, these data will allow the engineer to decide whether or not the particular site under investigation is suitable for the proposed activity. If the site is not suitable, it can be abandoned. If the site is suitable, the user can then indicate that design and construction operations are appropriate at this site. If the user decides that an insufficient amount of data is available on the characteristics of the rock units at a particular site or under a particular stress environment, he may then specify the performance of additional tests to furnish required information. On the basis of these additional tests, the user may decide that the site is unsuitable for the planned activity or he may elect to proceed with design and construction. During construction phases, performance of the rock units at a particular site should be monitored and evaluated. This information can then be returned to the data bank as case history information. After construction is completed, performance of the engineered facility and the rock units adjacent to that facility should be monitored. This performance monitoring also furnishes data which will be valuable in the location, design, and construction of other facilities. For this reason, performance monitoring data should be returned to the data bank as case history information. Ideally, the proposed rock evaluation program will be a self-sustaining, ever-expanding source of valuable information concerning the engineering properties and behavior of rock materials.

SUMMARY

Rock engineering includes a number of very significant major operations: engineering analysis and interpretation of geological information, prediction or determination of engineering properties of rock masses for use in analysis and design, and implementation of completed designs through construction activities in or on rock. Individuals drawn from various professions and disciplines are involved in these facets of rock engineering. To facilitate communication among these individuals and to assist in all facets

of rock engineering, a rock evaluation program has been proposed.

This evaluation program is especially useful for the planning, design, and construction of transportation facilities in and on rock. Data on engineering characteristics of rock units are utilized in a classification program. The classification program includes characterization of rock units on the basis of tests on intact samples and on the basis of evaluation of in-situ rock properties. Classifications can be modified for particular types of projects and use tables can be developed for the evaluation of rock units for use in specific purposes. A computerized system for the storage and retrieval of information has been developed. Data for inclusion in the information bank are derived from laboratory and field testing as well as monitoring of rock behavior during construction and subsequent operations of completed facilities. Current study efforts are directed toward verifying and improving the methodology set forth in this preliminary development of the rock evaluation program. It is hoped that development of this program will be of significant assistance to individuals engaged in rock engineering and, in particular, to individuals concerned with the planning, design, construction, and maintenance of transportation facilities in and on rock.

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TABLE 1

TYPICAL ATTRIBUTES OF INTACT ROCK SAMPLE CLASSIFICATION SYSTEMS

Anisotropy	Moisture Content
Lithology	Petrofabrics
Slake Durability	Porosity
Tensile Strength	Seismic Velocity
Compressive Strength	Shear
Density	Swelling
Drillability	Tangent Modulus
Dry Specific Gravity	Texture
Failure Characteristics	Toughness
Hardness	Unit Weight
Hysteresis	Weatherability

TABLE 2

TYPICAL ATTRIBUTES OF IN-SITU ROCK CLASSIFICATION SYSTEMS

Rock Quality	Intact Sample Tests
Bedding Character	Uniaxial Compression
Joint Frequency	Sonic
Weatherability or Alteration	Saturated Sonic
Lithology	Static Modulus
Deformation Characteristics	Point Loading
Velocity Ratio	Slake
Engineering Performance	In-Situ Tests
Slope Stability	Seismic
Powder Factor	Plate Jacking
	Permeability

	TENSILE STRENGTH		ANISOTROPY		DURABILITY		LITHOLOGY	
CLASS NO.	WORD DESCRIPTION	POINT-LOAD INDEX[a] (MPa)	WORD DESCRIPTION	STRENGTH ANISOTROPY INDEX[b]	WORD DESCRIPTION	SLAKE-DURABILITY INDEX[c] (percent)	SYMBOL	WORD DESCRIPTION
1	Very Strong	> 10	Isotropic	1.0 - 1.2	Very Durable	> 50	SS	Sandstone
2	Strong	3 - 10	Slightly Anisotropic	1.2 - 1.5	Durable	25 - 50	SH	Shale
3	Moderately Strong	1 - 3	Moderately Anisotropic	1.5 - 5.0	Moderately Alterable	10 - 25	LS	Limestone
4	Weak	0.3 - 1	Anisotropic	5 - 20	Alterable	5 - 10		
5	Very Weak	< 0.3	Very Anisotropic	> 20	Highly Alterable	< 5		

[a]Point-Load Index = Force at Failure/Square of Distance between Loaded Points in a test method developed by Franklin (1970)

[b]Strength Anisotropy = Maximum Strength/Minimum Strength

[c]Slake-Durability Index = Percent Retained on 2-mm Screen after slaking in a test developed by Franklin and Chandra (1972)

Example: 1 - LS - 2 - 1 indicates a very strong, slightly anisotropic, very durable limestone

Figure 1. Proposed Intact Sample Classification System.

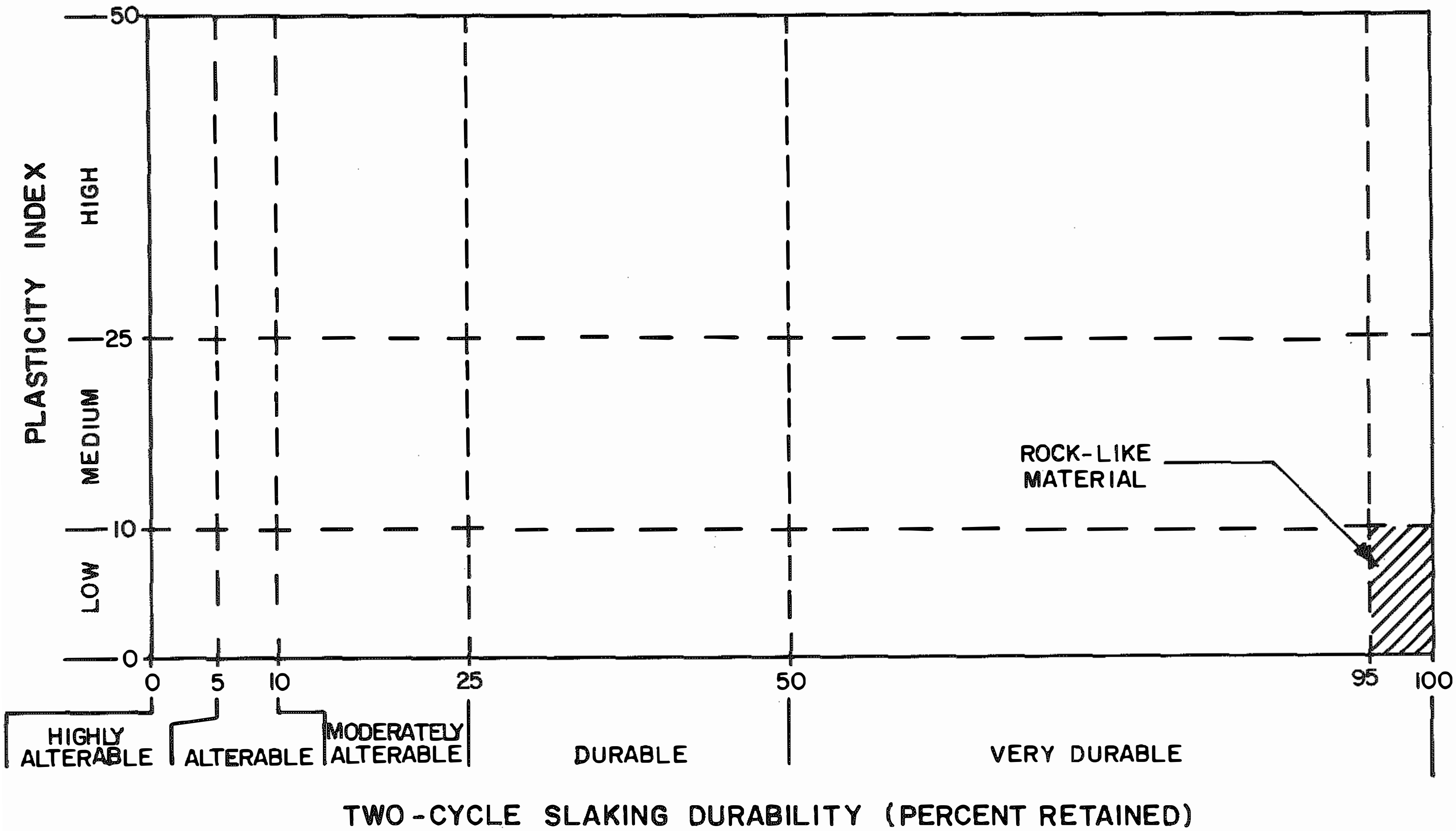

Figure 2. Durability-Plasticity Classification for Shales and Other Argillaceous Rocks.

	STRENGTH AND DEFORMABILITY – ROCK QUALITY (CONTINUITY)											
	BEDDING		JOINT SPACING		JOINT FREQUENCY			GROSS HETEROGENEITY		INTACT - IN-SITU REDUCTION FACTOR[a]		LITHOLOGY	
CLASS NO.	WORD DESCRIPTION	BEDDING THICKNESS (mm)	WORD DESCRIPTION	SPACING (mm)	WORD DESCRIPTION	JOINTS PER METER	JOINT INFILTRATION MATERIAL[a]	WORD DESCRIPTION	PERMEABILITY (nm/s)	DEGREE OF CORRELATION	VELOCITY RATIO[b]	SYMBOL	WORD DESCRIPTION
1	Very Thin	< 10	Very Close	< 10	Very Low	< 0.3	Air	Very Low	< 1	Excellent	> 0.8	SS	Sandstone
2	Thin	10 - 50	Close	10 - 50	Low	0.3 - 1.0	Water	Low	1 - 10	Good	0.6 - 0.8	SH	Shale
3	Medium	50 - 300	Moderately Close	50 - 300	Medium	1 - 2	Cohesionless Soil	Medium	10 - 100	Fair	0.4 - 0.6	LS	Limestone
4	Thick	300 - 1500	Wide	300 - 1500	High	2 - 4	Inactive Clay	High	100 - 1000	Poor	0.2 - 0.4		
5	Very Thick	> 1500	Very Wide	> 1500	Very High	> 4	Active Clay	Very High	> 1000	Very Poor	< 0.2		

[a] Subject to modification with further testing

[b] Velocity Ratio = In-Situ Sonic Velocity Intact Specimen Sonic Velocity

Figure 3. Proposed In-Situ Rock Classification System.

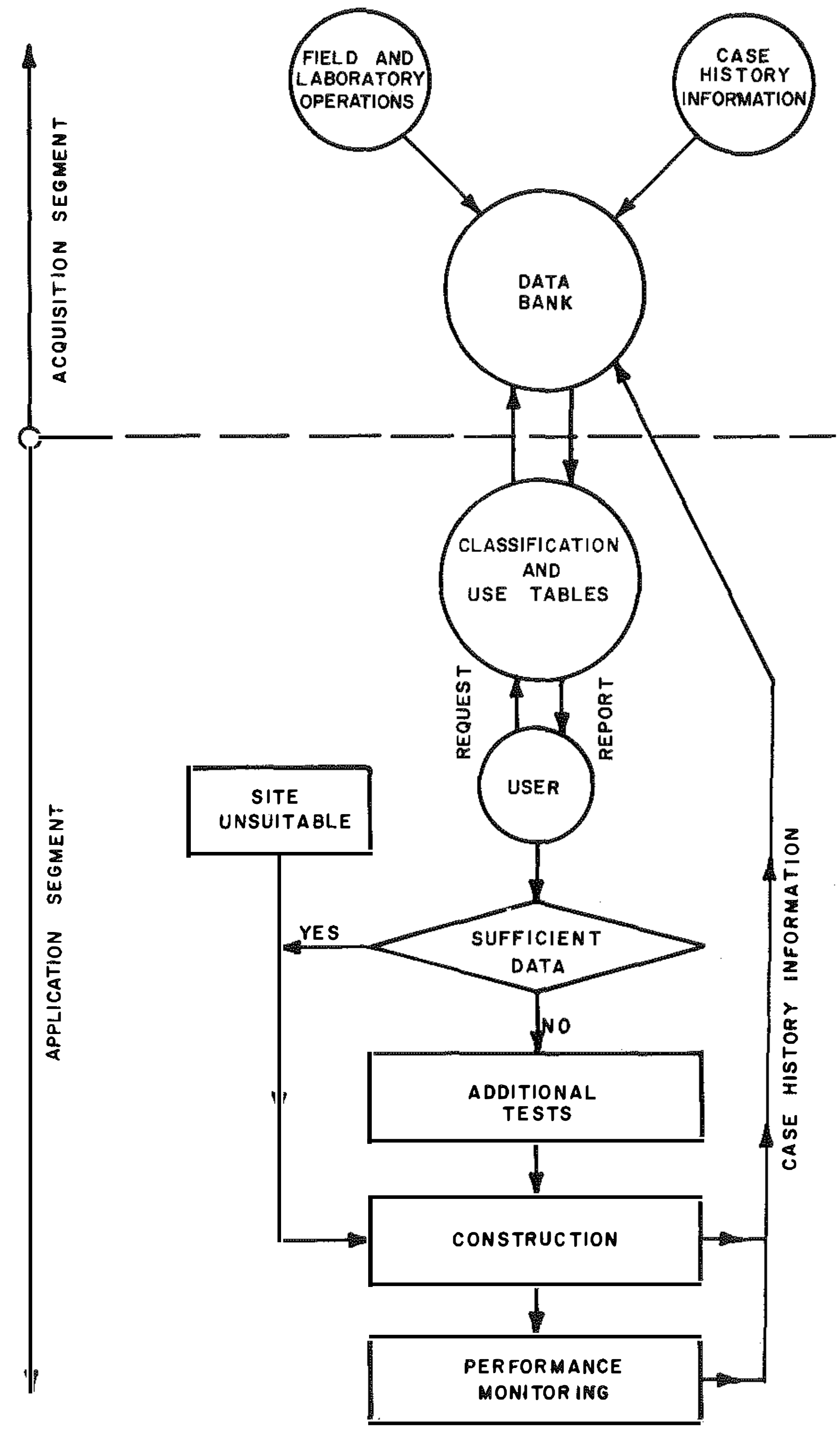

Figure 4. Schematic Diagram of the Proposed Rock Evaluation Schema.

Attribute	Subgroup	Group	Class	Category
STATE		LOCATION		CATEGORY 1
COUNTY				
PHYSIOGRAPHIC REGION				
USGS QUADRANGLE NUMBER				
LONGITUDE				
LATITUDE				
SAMPLE IDENTIFICATION NUMBER				
MAJOR GEOLOGICAL FORMATION				
ROCK TYPE (GENERIC)				
GROUND ELEVATION				
SAMPLE ELEVATION				
WATER TABLE ELEVATION				
SAMPLE ORIENTATION w/r GROUND SURFACE				
SAMPLE ORIENTATION w/r BEDDING PLANE				
METHOD OF OBTAINING SAMPLE				
RELEVANT COMMENTS				
COLOR		VISUAL	INTACT	CATEGORY 2
TEXTURE				
STRUCTURE				
GRAIN SIZE				
CALCIUM CARBONATE CONTENT				
FREE SWELL		INDEXING		
SLAKE DURABILITY INDEX				
POINT-LOAD INDEX				
STRENGTH ANISOTROPY INDEX				
LITHOLOGY				
STRENGTH SOFTENING				
TIME-STRAIN BEHAVIOR				
LABORATORY SONIC VELOCITY		PHYSIO-MECHANICAL RESULTS		
SHORE SCLEROSCOPE HARDNESS				
SCHMIDT "L" HAMMER HARDNESS				
UNCONFINED COMPRESSIVE STRENGTH				
TANGENT MODULUS				
NATURAL WATER CONTENT				
SATURATION WATER CONTENT				
APPARENT SPECIFIC GRAVITY				
BULK SPECIFIC GRAVITY				
APPARENT POROSITY				
APPARENT VOID RATIO				
BULK SPECIFIC GRAVITY (SSD)				
DEGREE OF SATURATION				
VOID INDEX				
DIRECT SHEAR PHI ANGLE				
DIRECT SHEAR COHESION				
DIRECT SHEAR TIME TO FAILURE				
TRIAXIAL COMPRESSION PHI ANGLE				
TRIAXIAL COMPRESSION COHESION				
LOS ANGELES ABRASION				
DEVAL ABRASION				
TRETON IMPACT				
FRACTURE ENERGY				
COST ANALYSIS DATA				
STRENGTH COEFFICIENT OF VARIATION				
SCALE EFFECT				
MINERALOGICAL COMPOSITION				
BEDDING THICKNESS	ROCK QUALITY	MASS DESCRIPTION (INDEXING)	IN SITU	
JOINT SPACING				
JOINT FREQUENCY				
JOINT INFILTRATION MATERIAL				
GROSS HETEROGENEITY				
VELOCITY RATIO				
JOINT ORIENTATION				
JOINT SURVEY				
CORE RECOVERY	CORE BORINGS	SECONDARY INDEXING		
RQD				
FRACTURE FREQUENCY				
WEIGHTED CORE LENGTH				
SCHMIDT HAMMER TEST				
GEOPHYSICAL SURVEYS				
FIELD TESTS				
LANDFORM CLASSIFICATION				
PREVIOUS EXPERIENCE				CATEGORY 3
CONSTRUCTION PRACTICES				
PERFORMANCE MONITORING				

Figure 5. Data Bank Attributes.

SITE-SAMPLE IDENTIFICATION SHEET

1. Sample Location

County	Physiographic Region	Station Number	USGS Quadrangle Number	Longitude	Latitude

2a. Sample I.D. ______________ 2b. Date Sampled ______________

3. Major Geological Formation from which Sample Was Taken ______________

4. Rock Type (Genetic) ______________

5. Ground Elevation ______________
☐ measured ☐ estimated

6. Elevation of Sample ______________
☐ measured ☐ estimated from ground surface

7. Elevation of Water Table ______________
☐ measured ☐ estimated from ground surface

8. Orientation of Sample with respect to Ground Surface
☐ GS ☐ GS ☐ GS $\theta=$ ____

9. Orientation of Sample with respect to Major Bedding Plane
☐ BP ☐ BP ☐ BP $\theta=$ ____

10. Method Used to Obtain Sample
☐ NX Core ☐ Quarry Sawn ☐ Other - explain
☐ Block ☐ Hand Tools ______________

11. Comments ______________

12. Signed ______________

INSTRUCTIONS

1. List sample location descriptors.

2. Sample I. D. will be quadrangle coordinates followed by sequential numbers for each site. Give date sample was obtained.

3. Enter the geological formation name, if known. If questionable, follow name with a question mark. If unknown, leave blank.

4. Generic term (i.e. limestone, sandstone, shale, granite, etc).

5. Indicate elevation to nearest foot (0.3 meter). Mark whether measured or estimated from a topographic map.

6. Indicate sample elevation to nearest foot (0.3 meter). Mark whether measured from ground surface or estimated.

7. Indicate water elevation, if determinable. Mark whether measured from ground surface or estimated.

8 - 9. Sample should be marked with a vertical arrow (↑) to indicate the top surface. Mark the appropriate block which relates this arrow to the surface in question. If on skew, indicate the approximate angle.

10. Check proper box. If other, explain briefly.

11. Include additional information which may be significant, i.e. general condition of rock at site (weathered, fractured, extensive joint systems, joint filling, solutioning, water seepage, etc.)

12. Name and signature of individual obtaining the sample.

Figure 6. Site-Sample Identification Sheet and Instructions.

CATEGORY 1, IDENTIFICATION DATA SUBFILE
(Data Card No. 1)

ATTRIBUTE	ATTRIBUTE CODE	LOCATION (COLUMN)	FORMAT	INSTRUCTIONS AND REMARKS
State	ST	1 - 2	I2	List the names of the states alphabetically and assign numbers sequentially from 01 through 50. Code number for Kentucky would be 17.
County	CO	3 - 5	I3	List the names of the counties within a state and assign numbers sequentially from 001.
Physiographic Region	PR	6 - 7	I2	Physiographic region from which the sample was obtained: 01 Purchase 02 Western Coal Field 03 Western Pennyroyal 04 Eastern Pennyroyal 05 Knobs 06 Outer Bluegrass 07 Inner Bluegrass 08 Eastern Coal Field
USGS Map	MN	8 - 11	I4	USGS number of geologic quadrangle map which encompasses the sample site. Examples: No. — Map Name 0246 — Kirsey 0763 — Lovelaceville 1025 — Addyston 0000 — Crofton (map not published)
Longitude	LON	12 - 15	I4	Longitude of the sample site will be described in terms of degrees and minutes. Seconds of longitude will be rounded to the nearest minute. Examples: 82° 34' 17" = 8234 86° 06' 47" = 8607 89° 15' 15" = 8915
Latitude	LAT	16 - 19	I4	Latitude of the sample site will be described in the same manner as longitude.
Sample Identification No.	ID	20 - 24	A5	Columns 20-21 -- Last two digits of the year in which the sample was obtained. Column 22 -- Month in which sample was obtained: 1 -- January 2 -- February • • • 9 -- September 0 -- October N -- November D -- December Columns 23-24 -- Specimen number.
Geological Formation	GF	25 - 27	I3	Major geological formation from which the sample was obtained will b...
				Ground elevation at sample site to nearest tenth of a meter.
		- 36	F4.1	Elevation from which sample was taken to nearest tenth of a meter.
Elevation	WTE	37 - 40	F4.1	Elevation of water table to nearest tenth of a meter.
Sample Orientation	SOG	41 - 42	F2.0	00 to 90 indicates the angle between the sample axis and the ground surface to the nearest degree.
Sample Orientation	SOB	43 - 44	F2.0	00 to 90 indicates the angle between the sample axis and the major bedding plane to the nearest degree.
Method of Obtaining Sample	MOS	45	I1	1 -- NX core 2 -- block sample 3 -- quarry sawn 4 -- hand tools 9 -- other (may be further delineated at a future time)
Relevant Comments	RC	46	I1	0 -- no comments 1 -- relevant comments available
	FREE1	47 - 48	I2	Blank (may be designated at a later time)

Figure 7. **Portion of Coding Instructions for Category 1 File Subsystem. (See the APPENDIX for complete coding instructions.)**

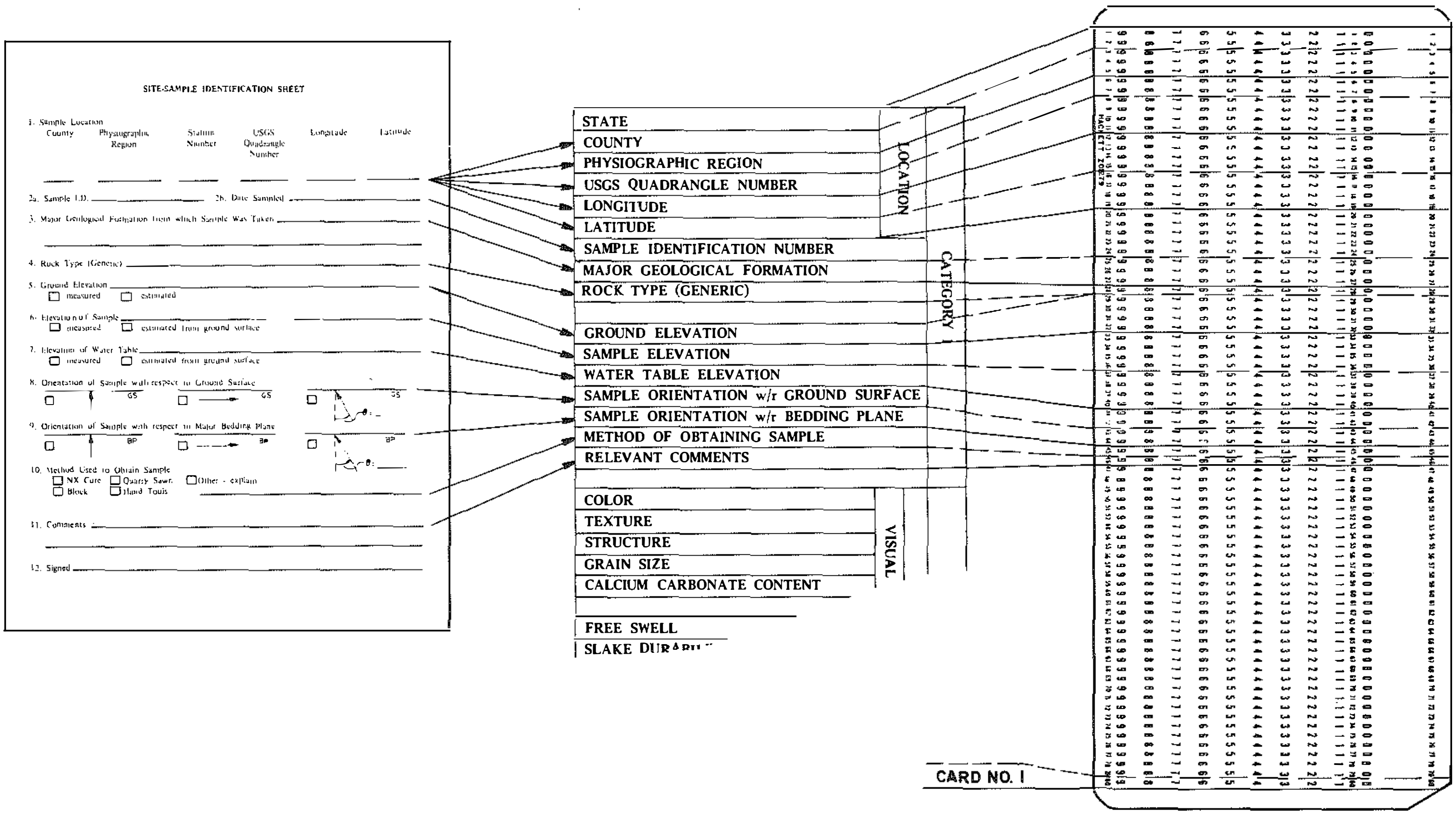

Figure 8. Category 1 (Site and Sample Description) File Subsystem.

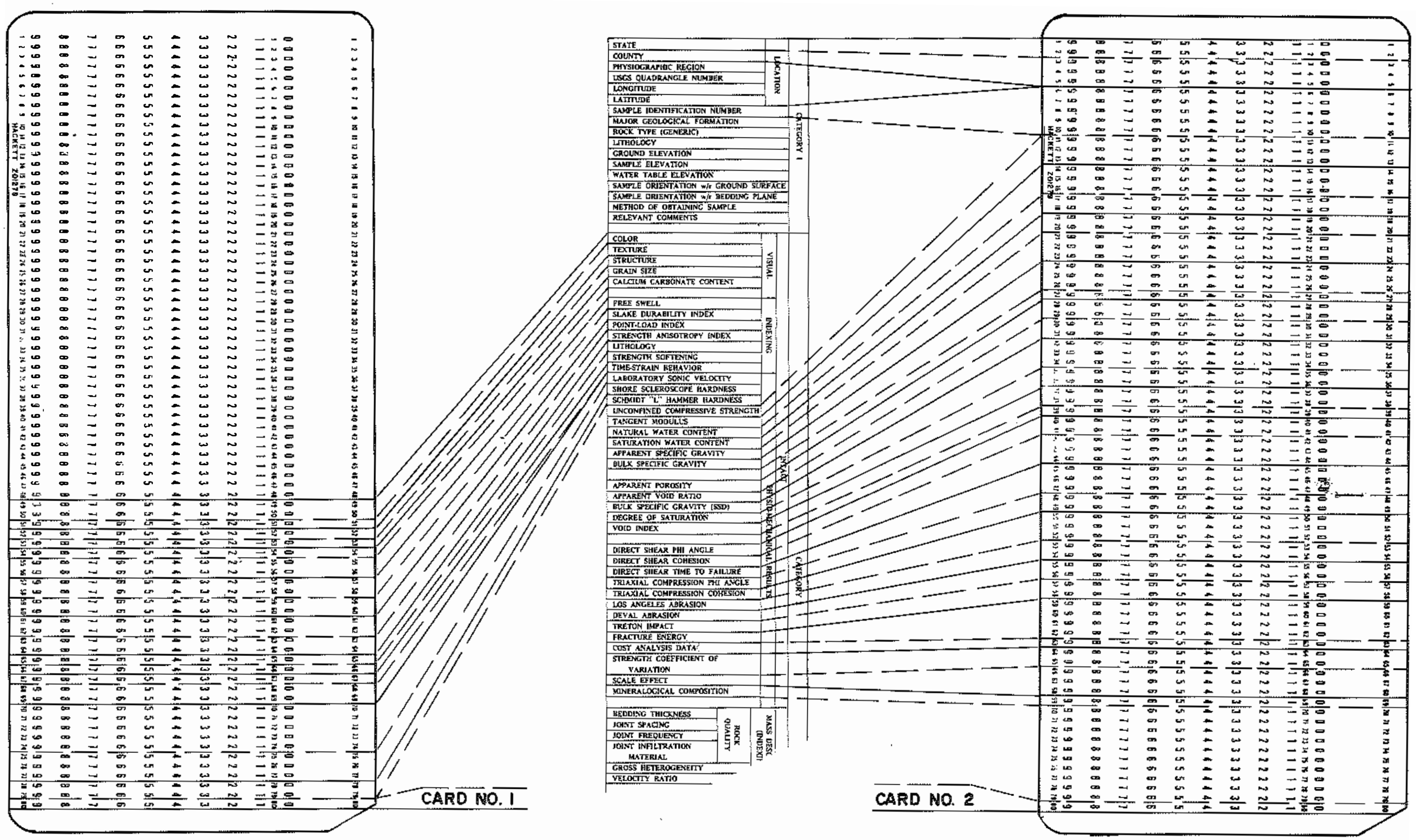

Figure 9. Category 2 (Intact Sample Data) File Subsystem.

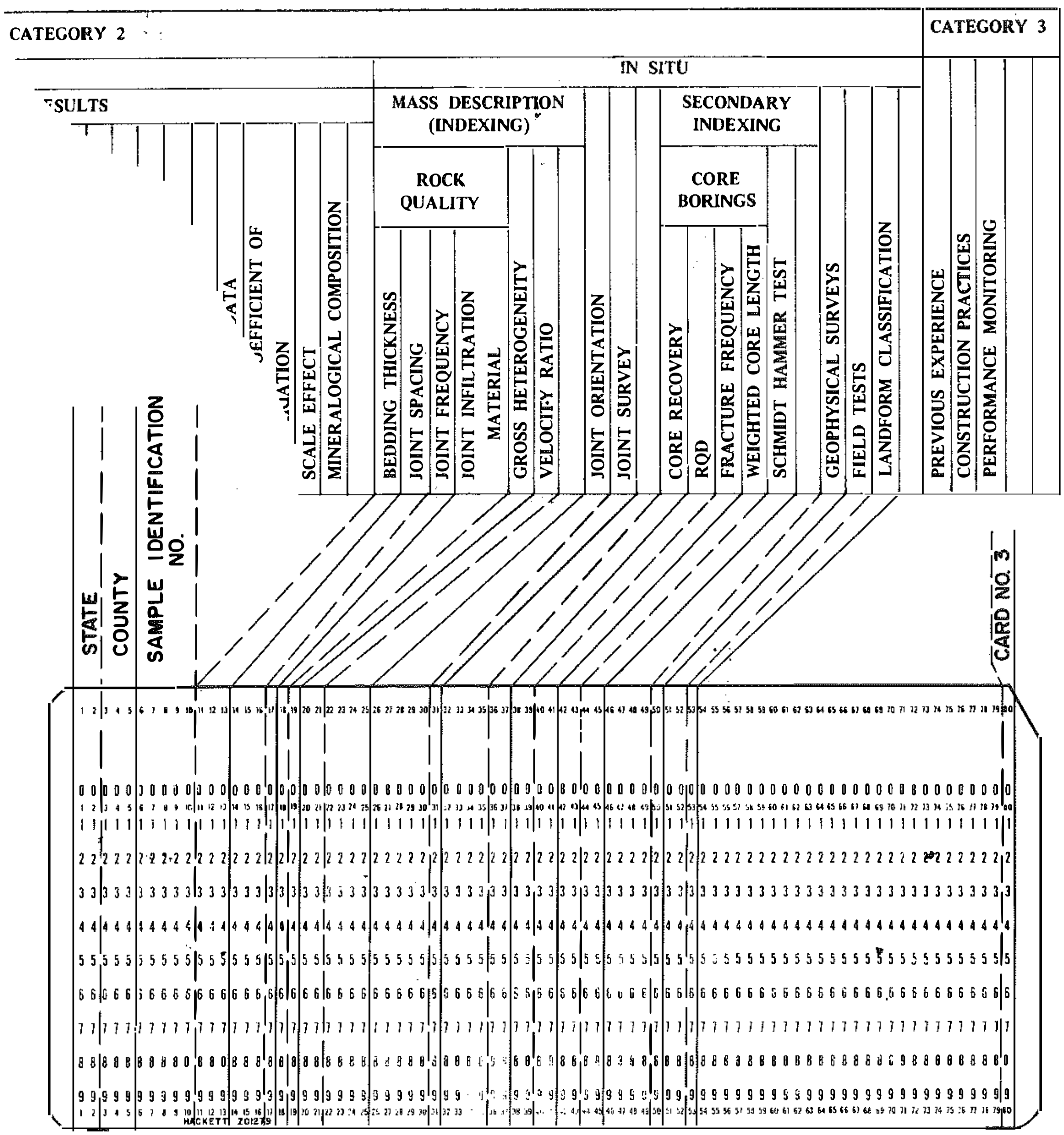

Figure 10. Category 2 (In-Situ Data) File Subsystem.

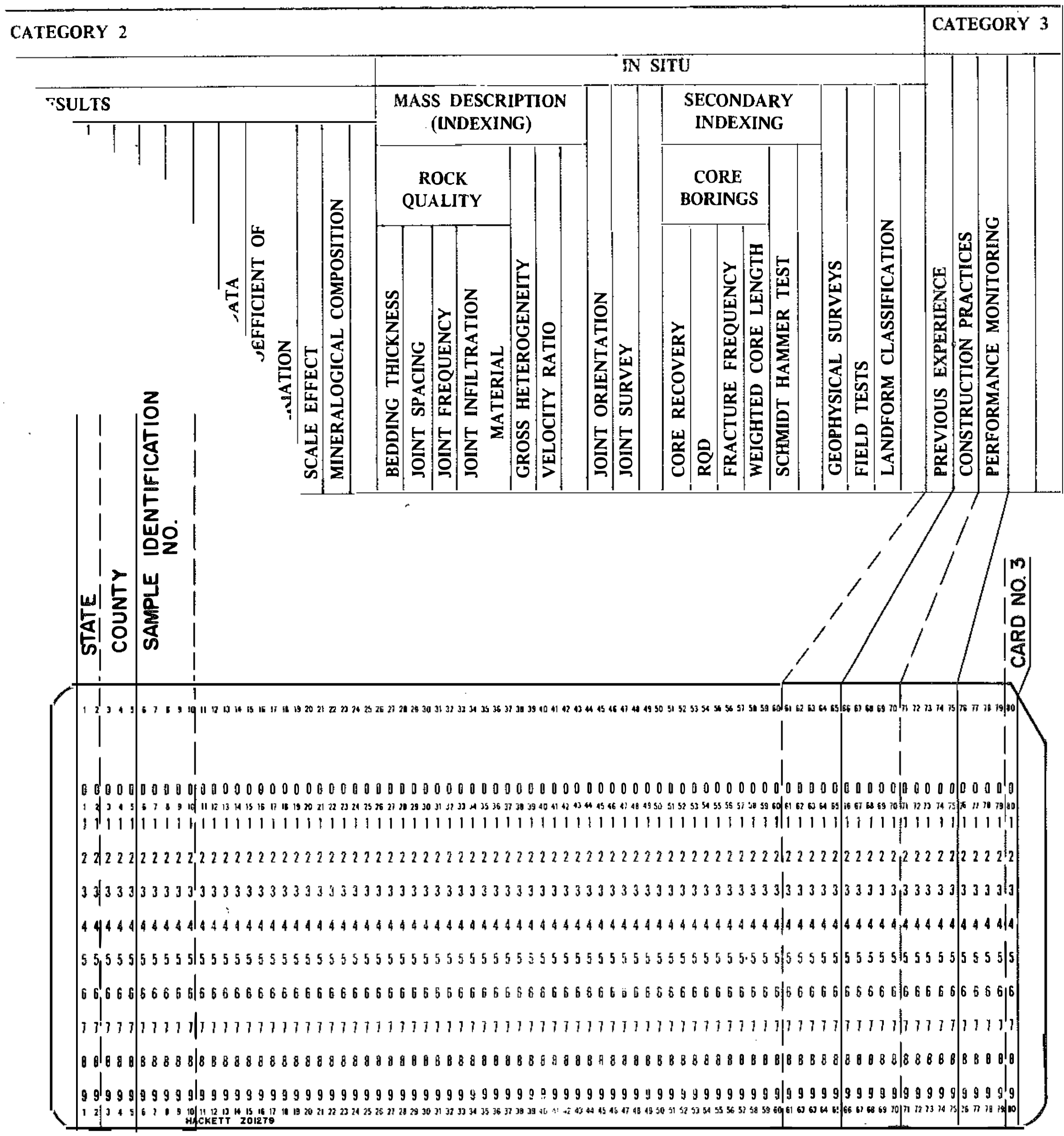

Figure 11. Category 3 (Case History Data) File Subsystem.

CLASSIFICATION ELEMENT	RANGE OF ACCEPTABLE VALUES						
	AGGREGATE	ROCKFILL	ROADWAY SURFACE	STABLE SLOPES	OTHER USES		
Point-Load Index							
Lithology							
Strength Anisotropy Index							
Slake-Durability Index							

Figure 12. Typical Format of a Use Table.

APPENDIX

FILE DEFINITION, FORMAT, AND CODING INSTRUCTIONS FOR ROCK DATA BANK

CATEGORY I, IDENTIFICATION DATA SUBFILE
(Data Card No. 1)

ATTRIBUTE	ATTRIBUTE CODE	LOCATION (COLUMN)	FORMAT	INSTRUCTIONS AND REMARKS
State	ST	1 - 2	I2	List the names of the states alphabetically and assign numbers sequentially from 01 through 50. Code number for Kentucky would be 17.
County	CO	3 - 5	I3	List the names of the counties within a state and assign numbers sequentially from 001.
Physiographic Region	PR	6 - 7	I2	Physiographic region from which the sample was obtained: 01 Purchase 02 Western Coal Field 03 Western Pennyroyal 04 Eastern Pennyroyal 05 Knobs 06 Outer Bluegrass 07 Inner Bluegrass 08 Eastern Coal Field
USGS Map	MN	8 - 11	I4	USGS number of geologic quadrangle map which encompasses the sample site. Examples: No. Map Name 0246 Kirsey 0763 Lovelaceville 1025 Addyston 0000 Crofton (map not published)
Longitude	LON	12 - 15	I4	Longitude of the sample site will be described in terms of degrees and minutes. Seconds of longitude will be rounded to the nearest minute. Examples: 82° 34' 17" = 8234 86° 06' 47" = 8607 89° 15' 15" = 8915
Latitude	LAT	16 - 19	I4	Latitude of the sample site will be described in the same manner as longitude.
Sample Identification No.	ID	20 - 24	A5	Columns 20-21 -- Last two digits of the year in which the sample was obtained. Column 22 -- Month in which sample was obtained: 1 -- January 2 -- February • • • 9 -- September 0 -- October N -- November D -- December Columns 23-24 -- Specimen number.
Geological Formation	GF	25 - 27	I3	Major geological formation from which the sample was obtained will be designated as follows: **QUARTERNARY** 001 Alluvium

002 Loess
003 Continental Deposits

TERTIARY
004 Jackson
005 Clairborne
006 Wilcox
007 Porter's Creek

CRETACEOUS
008 Eutaw
009 Tuscaloosa

PENNSYLVANIAN
Western Coal Field
010 Henshaw-Dixon
011 Lisman
012 Carbondale
013 Tradewater
014 Caseyville

Eastern Coal Field
015 Conemaugh
016 Allegheny
017 Breathitt
018 Lee

MISSISSIPPIAN
Fluospar Region
019 Kinkaid
020 Degonia
021 Clore
022 Palestine
023 Menard
024 Waltersburg
025 Vienna
026 Tar Springs
027 Glen Dean
028 Hardinsburg
029 Golconda
030 Cypress
031 Paint Creek
032 Bethel
033 Renault
034 Aux Vases

West of Arch
035 Elwren
036 Reelsville
037 Sample
038 Beaver Bend
039 Paoli

East of Arch
040 Bangor
041 Hartselle
042 Monteagle

043 Saint Genevieve
044 Saint Louis
045 Salem
046 Warsaw (Harrodsburg)

047 Fort Payne
048 Borden
049 Sunbury
050 Berea
051 Bedford

DEVONIAN
052 New Albany

West of Arch
053 Sellersburg
054 Jeffersonville

East of Arch
055 Boyle

SILURIAN
West of Arch
056 Louisville
057 Waldron
058 Laurel
059 Osgood
060 Brassfield

East of Arch
061 Boyle
062 Bisher
063 Crab Orchard
064 Brassfield

ORDOVICIAN
West of Arch
Southwest Blue Grass
065 Drakes
066 Ashlock
067 Grant Lake
068 Calloway Creek
069 Garrard
070 Clays Ferry

East of Arch
Northwest Blue Grass
071 Drakes
072 Bull Fork
073 Grant Lake
074 Fairview
075 Kope
076 Clays Ferry
077 Lexington Limestone
078 High Bridge

998 Other
999 Not Known

Lithology	LITHO	28	I1	Generic rock type of the sample (ASTM C 119) is indicated as follows: 1 -- limestone (ASTM C 568) 2 -- shale or transitional material (ASTM C 294) 3 -- sandstone (ASTM C 616) 4 -- siltstone (ASTM C 294) 5 -- granite (ASTM C 615) 6 -- conglomerate

				9 -- other (may be further delineated at a future time)
Ground Elevation	GEL	29 - 32	F4.1	Ground elevation at sample site to nearest tenth of a meter.
Sample Elevation	SE	33 - 36	F4.1	Elevation from which sample was taken to nearest tenth of a meter.
Water Table Elevation	WTE	37 - 40	F4.1	Elevation of water table to nearest tenth of a meter.
Sample Orientation	SOG	41 - 42	F2.0	00 to 90 indicates the angle between the sample axis and the ground surface to the nearest degree.
Sample Orientation	SOB	43 - 44	F2.0	00 to 90 indicates the angle between the sample axis and the major bedding plane to the nearest degree.
Method of Obtaining Sample	MOS	45	I1	1 -- NX core 2 -- block sample 3 -- quarry sawn 4 -- hand tools 9 -- other (may be further delineated at a future time)
Relevant Comments	RC	46	I1	0 -- no comments 1 -- relevant comments available
	FREE1	47 - 48	I2	Blank (may be designated at a later time)

CATEGORY 2, INTACT SPECIMEN DATA SUBFILE
Part 1
(Data Card No. 1)

Color	COL	49 - 50	I2	The hue of the specimen shall be described in terms of ten basic colors: 10 -- black 20 -- blue 30 -- brown 40 -- gray 50 -- green 60 -- olive 70 -- orange 80 -- red 90 -- yellow 00 -- white Other colors can be indicated using combinations of the above code numbers. Using "black" to represent "dark" and "white" to represent "light," the following are examples: dark brown = black + brown = 10 + 30 = 13 light green = white + green = 00 + 50 = 05 greenish yellow = green + yellow = 50 + 90 = 59 grayish orange = gray + orange = 40 + 70 = 47 purple = blue + red = 20 + 80 = 28 (Note that the final zero of the basic code numbers is dropped to obtain the combined codes.)
Texture	TEX	51	I1	1 -- crystalline 2 -- crystalline-indurated 3 -- indurated 4 -- compact 5 -- cemented

Structure	STR	52	I1	1 -- homogeneous 2 -- lineated 3 -- intact-foliated 4 -- fracture-foliated
Grain Size	GS	53	I1	1 -- coarse grained 2 -- medium grained 3 -- fine grained
Calcium Carbonate Content	CCC	54	I4	1 -- calcareous 2 -- partially calcareous 3 -- non-calcareous
	FREE2	55 - 56	I2	Blank (may be designated at a later time)
			Part 2	
Free Swell	FS	57 - 58	I2	Unconfined swell (Franklin, 1972) input as an integer from 00 to 99, indicating values from 1 x 10^{-3} to 99 x 10^{-3} mm.
Slake Durability Index	SDI	59 - 60	F2.0	Percentage of slaking (Franklin and Chandra, 1971) to nearest percent. Input 100 percent as 99.
Point-Load Index	TSI	61 - 62	F2.0	Tensile strength (maximum value from Point Load Test (Brock and Franklin, 1972)) in units of MPa. Range of allowable input values is 01 MPa to 99 MPa.
Strength Anisotropy Index	SAI	63 - 64	F2.0	Ratio of maximum tensile strength to minimum tensile strength (Point Load Test (Franklin, 1970; Tockstein and Palmer, 1974)). 01 -- isotropic • • • 99 -- extremely anisotropic
Lithology	LITH	65	I1	See Column 28, Cateogry 1.
Strength Softening	SS	66	I1	Strength decrease in compression softening test (Morgenstern and Eigerbrod, 1974) is indicated as follows: 0 -- no data available 1 -- mudstones -- strength lose < 40 percent 2 -- clays -- strength lose > 60 percent 3 -- hard clays -- > 50 percent strength lose within days 4 -- stiff clays -- > 50 percent strength lose within hours 5 -- medium to soft clays -- complete disintegration occurs immediately
Time-Strain Behavior	TSB	67	I1	Time-strain behavior, at 50 percent of unconfined compressive strength, under a sustained uniaxial loading (Coates and Parsons, 1966; Parsons and Hedley, 1966) is indicated as follows: 0 -- no data available 1 -- elastic (creep rate < 2 μm/m/hr) 2 -- viscous (creep rate > 2 μm/m/hr) 3 -- visco-elastic (creep rate $\approx$ 2 μm/m/hr)

	FREE3	68 - 69	I2	Blank (may be designated at a later time)

Part 3

Laboratory Sonic Velocity	LSV	70 - 74	F5.0	Sonic velocity (Thill, et al., 1968) in cps (ASTM D 2845).
Shore Scleroscope Hardness	SSH	75 - 77	F3.0	Rebound hardness measured by the Shore scleroscope tester.
Schmidt Hammer Hardness	SHH	78 - 79	F2.0	Rebound hardness (Hucka, 1965) using Type L Schmidt rebound hammer.
	CARD1	80	I1	1-punch for Card No. 1

CATEGORY 2, INTACT SPECIMEN DATA SUBFILE (Cont'd)
Part 3 (Cont'd)
(Data Card No. 2)

State	ST	1 - 2	I2	See Columns 1-2, Card 1.
County	CO	3 - 5	I3	See Columns 3-5, Card 1.
Sample Identification No.	ID	6 - 10	A5	See Columns 20-24, Card 1.
Unconfined Compressive Strength	UCS	11 - 13	F3.1	Unconfined compressive strength (Green and Perkins 1968; Franklin 1972) in units of tenths of GPa (ASTM D 2938).
Tangent Modulus	TM50	14 - 16	F3.1	Tangent modulus at a stress level of 50 percent of the ultimate unconfined compressive strength (Deere and Miller, 1966) in units of tenths of GPa (ASTM D 3148).
Natural Water Content	NWC	17 - 18	F2.0	Natural water content to the nearest percent (Franklin, 1972).
Saturation Water Content	SWC	19 - 20	F2.0	Water content to the nearest percent to fully saturate the sample (Duncan, 1969; Ruiz, 1966).
Apparent Specific Gravity	ASG	21 - 23	F3.2	$ASG = W_s/V_s\gamma_w$ where W_s = weight of oven-dry sample, V_s = volume of solids plus impermeable voids, and γ_w = density of water.
Bulk Specific Gravity	BSG	24 - 26	F3.2	$BSG = W_s/V\gamma_w$ where V = total volume of sample (solids and voids)(Duncan, 1969; Ruiz, 1966; ASTM E 12).
	FREE4	27	I1	Blank (may be designated at a later time)
Apparent Porosity	AP	28 - 29	F2.0	Ratio of volume of permeable voids to total volume to the nearest percent (Ruiz, 1966).

Apparent Void Ratio	AVR	30 - 31	F2.0	Ratio of volume of permeable voids to volume of solids plus impermeable voids.
Bulk Specific Gravity (SSD)	SSDG	32 - 34	F3.2	SSDG = bulk specific gravity (saturated surface dry) = $W_t/V\gamma_w$ where W_t = total weight of saturated surface dry sample.
Degree of Saturation	DOS	35 - 36	F2.0	Ratio of natural water content to saturation water content to the nearest percent.
Void Index	VI	37 - 38	F2.0	Degree of saturation of sample to the nearest percent after immersion in water for 1 hour (Franklin, 1972).
	FREE5	39	I1	Blank (may be designated at a later time)
Direct Shear Phi Angle	DSP	40 - 41	F2.0	Angle of internal friction in degrees (Giuseppe, 1970; Mellinger and Kenty, 1971).
Direct Shear Cohesion	DSC	42 - 44	F3.1	Cohesion in units of tenths of GPa.
Direct Shear Time to Failure	DST	45 - 47	F3.1	Time to failure in units of tenths of a minute.
Triaxial Compression Strength Phi Angle	TSCP	48 - 49	F2.0	Angle of internal friction in degrees (Heck, 1968; Moretto and Bolognesi, 1970; ASTM D 2664).
Triaxial Compression Strength Cohesion	TCSC	50 - 52	F3.1	Cohesion in units of tenths of GPa.
Los Angeles Abrasion	LAA	53 - 54	F2.0	Percentage wear (abrasion or wear test) to the nearest percent (ASTM C 131).
Deval Abrasion	DA	55 - 56	F2.0	Percentage lose (abrasion or wear test) to the nearest percent (Ruiz, 1966; ASTM D 2 (withdrawn in 1972)).
Treton Impact	TI	57 - 58	F2.0	Percentage lose (impact test) to the nearest percent (Ruiz, 1966).

Part 4

Fracture Energy	FE	59 - 62	F4.2	Fracture energy from an unconfined compressive test (Krech and Chamberlain, 1972) in units of hundredths of J/cm^2.
Cost Analysis Data	CAD	63	I1	The existence and availability of cost analysis data[c] will be indicated as follows (Bernaix, 1969): 0 -- no information available 1 -- cost analysis data available 2 -- rock classification based on rock properties, generic rock type, and fracture energy is available for a particular physiographic region 3 -- other information available

Part 5

Strength Coefficient of Variation	COV	64 - 65	F2.2	Unconfined (uniaxial) compressive strength coefficient of variation defined as the standard deviation of observed strengths to the mean of observed strengths (Bernaix, 1969).
Scale Effect	SE	66 - 68	F3.1	Ratio of unconfined compressive strength of a 10-mm diameter specimen to unconfined compressive strength of a 60-mm diameter specimen.

Part 6

Mineralogical Composition	MC	69	I1	0 -- no information available 1 -- quartzofeldspathic (acid igneous rocks, quartz sandstones, gneisses, and granulites) -- usually strong and brittle 2 -- lithic/basic (basic igneous rocks, lithic and greywacke sandstones, and amphibolites) -- usually strong and brittle 3 -- pelitic (clay) (mudstones, slates, and phyllites) -- often viscous, plastic, and weak 4 -- pelitic (mica) (schists) -- often fissile and weak 5 -- saline/carbonate (limestones, marbles, dolomites, salt rocks) -- sometimes viscous, often plastic and weak
	FREE6	70 - 79	I10	Blank (may be designated at a later time)
	CARD2	80	I1	2-punch for Card No. 2

CATEGORY 2, IN-SITU DATA SUBFILE
Part 1
(Data Card No. 3)

State	ST	1 - 2	I2	See Columns 1-2, Card 1.
County	CO	3 - 5	I3	See Columns 3-5, Card 1.
Sample Identification No.	ID	6 - 10	A5	See Columns 20-24, Card 1.
Bedding Thickness	BT	11 - 13	F3.0	Bedding thickness to nearest centimeter.
Joint Spacing	JS	14 - 16	F3.0	Average or predominate joint spacing to nearest centimeter.
Joint Frequency	JF	17	I1	0 -- less than one joint per 3 meters 1 -- one joint per 3 meters 2 -- two joints per 3 meters • • • 8 -- eight joints per 3 meters 9 -- nine or more joints per 3 meters

Joint Infiltration Material	JIM	18	I1	0 -- no data available 1 -- air 2 -- water 3 -- cohesionless soil 4 -- inactive clay 5 -- active clay 6 -- gravel 9 - other
Gross Heterogeneity	GH	19	I1	Directional permeability of the massif as measured by the Menard Pressure Meter (Menard, 1966), in units of nanometers per second, as follows: 0 -- no data available 1 -- $GH < 1$ nm/s 2 -- $1 \leqslant GH < 5$ 3 -- $5 \leqslant GH < 10$ 4 -- $10 \leqslant GH < 50$ 5 -- $50 \leqslant GH < 100$ 6 -- $100 \leqslant GH < 500$ 7 -- $500 \leqslant GH < 1000$ 8 -- $1000 \leqslant GH < 1500$ 9 -- $GH \geqslant 1500$
Velocity Ratio	VR	20 - 21	F2.1	Ratio of field seismic velocity to laboratory sonic velocity (Columns 70-74, Card No. 1) (Onodera, 1962).
	FREE7	22 - 25	I4	Blank (may be designated at a later time)

Part 2

Joint Orientation	JO	26 - 30	I5	The prevailing joint orientation is recorded as a combination of two intergers (00 to 90) representing the angle of dip of the joint system and three intergers (000 to 360) representing the azimuth of the joint system strike (e.g. a dip of 9° East would be recorded as 09090).
Joint Survey	JSUR	31	I1	Existence of a joint survey is indicated as follows: 0 -- no survey data available 1 -- survey data available
	FREE8	32 - 35	I4	Blank (may be designated at a later time)

Part 3

Core Recovery	CR	36 - 37	F2.0	Ratio of length of core obtained from a drilling interval to the total length of the cored interval, expressed to the nearest percent.
RQD	RQD	38 - 39	F2.0	Sum of the lengths of pieces of sound core 10 cm or more in length expressed as a percentage of the total length of the cored interval (Deere, 1963).
Fracture Frequency	FF	40 - 41	F2.0	Average linear length of rock blocks which constitute the total cored rock massif to the nearest centimeter (Franklin, 1970).

Weighted Core Length	WCL	42 - 43	F2.0	Ratio of the sum of core pieces $>$ 30 cm in length plus sum of the squares of core pieces $<$ 30 cm but $>$ 3 cm in length to the total length of the core run, expressed to the nearest percent (Coon, 1968).
Schmidt Hammer	SH	44 - 45	F2.0	Mean of at least ten trails on a prepared surface (Hucka, 1965).
	FREE9	46 - 49	I4	Blank (may be designated at a later time)

Part 4

Geophysical Surveys	GEOS	50	I1	Existence of a geophysical survey is indicated as follows: 0 -- no geophysical survey 1 -- refraction seismic survey 2 -- reflection seismic survey 3 -- combination of 1 and 2 4 -- gravity survey 5 -- magnetic survey 6 -- electrical survey 7 -- radioactive survey 8 -- all of the above 9 -- limited data
Field Tests	FT	51 - 52	I2	Existence of field test data is indicated as follows: 00 -- no field test data available 01 -- sliding test 02 -- shear test 03 -- uniaxial jacking test 04 -- plate loading test 05 -- percolation test 06 -- tank test 07 -- cable test 08 -- borehole deformation test 99 -- other
Landform Classification	LC	53	I1	Existence of landform classification data is indicated as follows: 0 -- no data available 1 -- Terrain Classification (Stepanović, 1960; Jovan and Božinović, 1966) 2 -- PUCE (Aitchison and Grant, 1967) 3 -- Physiographic Classification (Brink and Partridge, 1967) 4 -- Landform Classification (Wahlstrom, 1973). 9 -- other
	FREE10	54 - 60	I7	Blank (may be designated at a later time)

CATEGORY 3, CASE HISTORY SUBFILE
(Data Card No. 3)

Previous Experience	PE	61 - 65	I5	Existence of data on previous experience is indicated as follows: 00001 -- no data available 00002 -- data related primarily to physiographic regions 00003 -- data related primarily to rock types 00004 -- data of a general nature

Construction Practices	CP	66 - 70	I5	Existence of data concerning construction practices is indicated as follows: 0000I -- no data available 00002 -- data related primarily to physiographic regions 00003 -- data related primarily to rock types 00004 -- data of a general nature
Performance Monitoring	PM	7I - 75	I5	Existence of data on performance monitoring is indicated as follows: 00001 -- no data available 00002 -- data related primarily to physiographic regions 00003 -- data related primarily to rock types 00004 -- data of a general nature
	FREE11	76 - 79	I4	Blank (may be designated at a later time)
	CARD3	80	I1	3-punch for Card No. 3

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